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LIDAR MEASUREMENTS OF ANTARCTIC STRATOSPHERIC AEROSOLS DURING 1983, 1984 AND 1985: EFFECT OF VOLCANIC ERUPTION OF EL CHICHÓN

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Abstract: Measurements on stratospheric aerosols were carried out at Syowa Station (69°00′S, 39°35′E) in 1983, 1984 and 1985. The volcanic eruption of El Chichón (spring 1982, Mexico) possibly disturbed the Antarctic winter stratosphere. The decay time scale of volcanic enhanced aerosol layer is about 9 months.

1. Introduction

Previous volcanic eruptions are known to have injected volcanic materials into the stratosphere. The eruptions of El Chichón volcano of Mexico, between late March and early April 1982, are known to have ejected debris to stratospheric heights. Large increase in stratospheric aerosols and their associated optical effects were observed at a number of locations (*e.g.*, IWASAKA *et al.*, 1983; REITER *et al.*, 1983; ADRIANI *et al.*, 1983; CLEMESHA and SIMONICH, 1983).

According to a chemical analysis of ice core sampled at Dome C, Antarctica, the variations of the enrichment factors of "Anomalous Enriched Elements", Pb, Cd, Zn and Cu during the period from 1914 to 1974 coincided fairly well with the variations of the past volcanic activity (MITCHELL, 1975). BOUTRON (1980) also reported that the period of 1880's to 1977 was characterized by several exceptionally strong volcanic eruptions which produced a worldwide effect.

At Syowa Station (69°00′S, 39°35′E) on January 25, 1983, a particle was found in the upper troposphere (2 km below the local tropopause), which had electron-dense TEM shape and was coated by liquid, possibly sulfuric acid solution (IWASAKA *et al.*, 1985c). Such particle had been frequently observed in the stratosphere immediately after severe volcanic eruptions. IWASAKA *et al.* (1985c) speculated that the particle was originated from El Chichón volcanic cloud particles which were transported to the southern stratosphere and fell down to the Antarctic troposphere.

Lidar measurements on Antarctic stratospheric aerosols at Syowa Station from

1983 to 1985 are presented here, and the effect of El Chichón eruption on the Antarctic stratospheric particles is discussed. The observations covered the initial stage and possibly maximum amount of stratospheric aerosols following the eruptions of El Chichón.

2. Lidar Measurements

The details of lidar system used here have already been described in other papers (IWASAKA *et al.*, 1985b, d).

We carried out lidar observations at wavelength=0.6943 μm with the height resolution of 0.5 km, laser out put energy in the range of 0.2–1.0 J/pulse and the repetition rate 0.5 Hz.

The scattering ratio of particulate matter is defined by,

$$R=[B_1+B_2]/B_1\,, \tag{1}$$

where B_1 and B_2 are the backscattering coefficients of air molecules and aerosol particles respectively. In order to estimate the value of scattering ratio, we used "Matching Method" (*e.g.*, RUSSELL *et al.*, 1977). Density profile of air molecules was estimated on the basis of the routine radiosonde measurements at Syowa Station.

The backscattering coefficient of particulate matter is deduced by,

$$B_2(Z)=[R-1]B_1(Z)\,. \tag{2}$$

The vertically integrated backscattering coefficient of particles in the stratosphere is given by,

$$\int_{Z_1}^{Z_2} B_2(Z)\mathrm{d}Z\,, \tag{3}$$

where Z_1 and Z_2 are the heights of the top of the particle layer and of the tropopause, respectively, and there are the parameters which depend optically to particle content in the stratosphere (column density).

3. Results

Temporal change of the vertically integrated particulate backscattering coefficient is shown in Figs. 1a, 1b and 1c.

In summer at high latitudes it is impossible to measure backscattering light of stratospheric particles because of the solar radiation throughout the day. During the winter, observations were carried out in 1983 and 1985, but in 1984.

3.1. Winter enhancement

Winter enhancement is an important factor characterizing Antarctic stratospheric aerosols (MCCORMICK *et al.*, 1985). Lidar measurements made in the winter of 1983 at Syowa Station showed extremely enhanced stratospheric aerosol layer (IWASAKA, 1985, 1986a, b; IWASAKA *et al.*, 1985a, b). The observations in the winter of 1985 also showed the winter enhancement, and confirmed the speculation that the enhancement

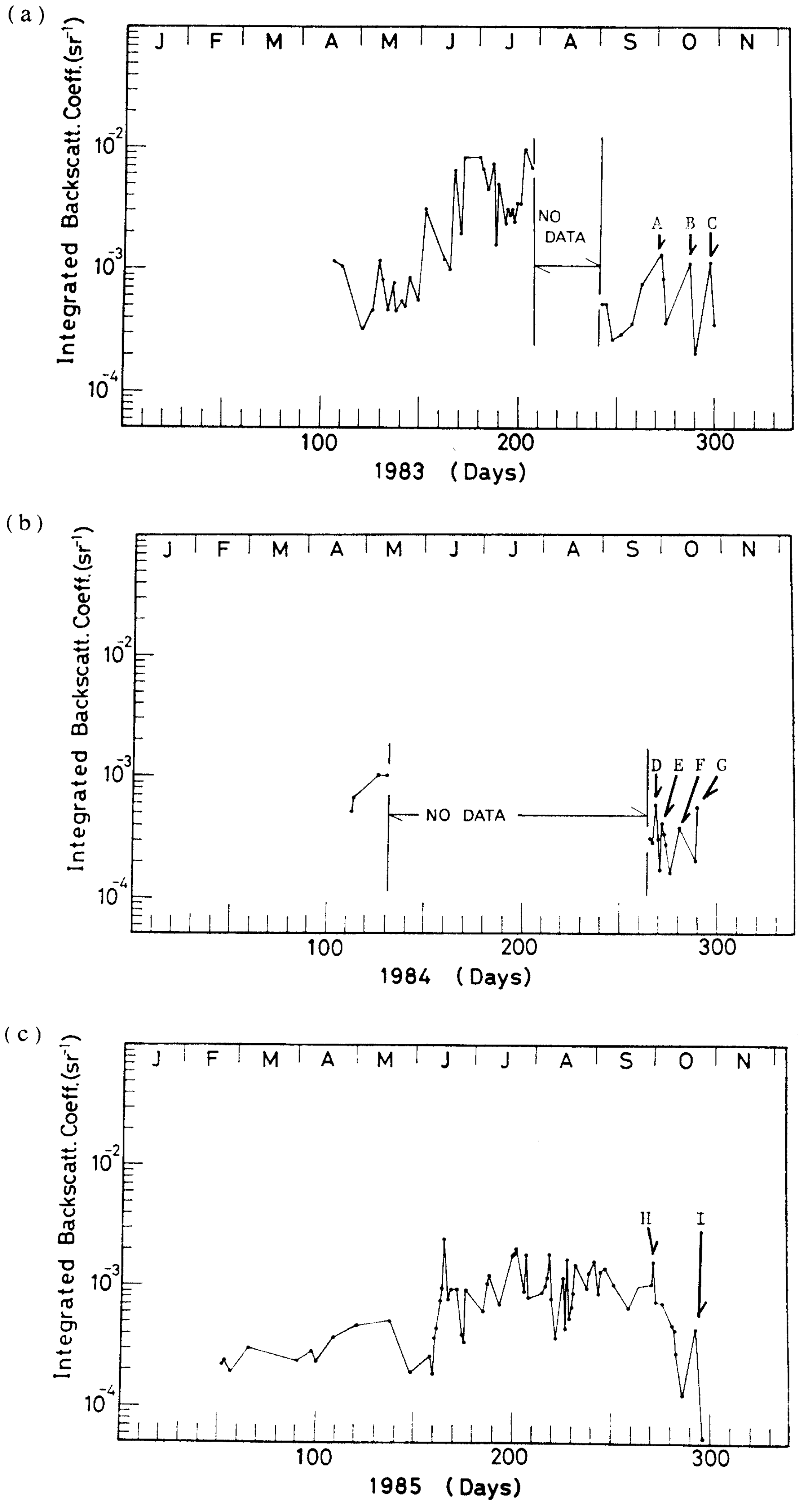

Fig. 1. Vertically integrated backscattering coefficient of particles, at Syowa Station (69°00′S, 39°35′E). Measurements in 1983 (a), 1984 (b), and 1985 (c).

seems to take place in every winter at Syowa Station (IWASAKA, 1985; IWASAKA *et al.*, 1985a).

3.2. Clean stratosphere in early spring

IWASAKA (1986a) pointed that a minimum amount of particles was found in early spring (September) of 1983. The same feature was noticeable in the measurements of October 1985. The average value of in the spring (September and October) of 1984 is at a little heigher levels in comparison with the observations in 1983 and 1985. However, the minimum amount in the spring of 1984 was between the minimum values of 1983 and 1985.

3.3. Disturbance due to sudden warming

Figure 2 shows the temperature profile and its change in 1985 (August, September and October). Increases in particle concentration were frequently observed during stratospherics sudden warmings. The peak "I" in Fig. 1 is a good example for the particle increase during a sudden warming. The peaks B, C, F, G, and I are ones which appeared in association with sudden warmings. The results suggest that the content of particles is strongly controlled by dynamical air motions in spring.

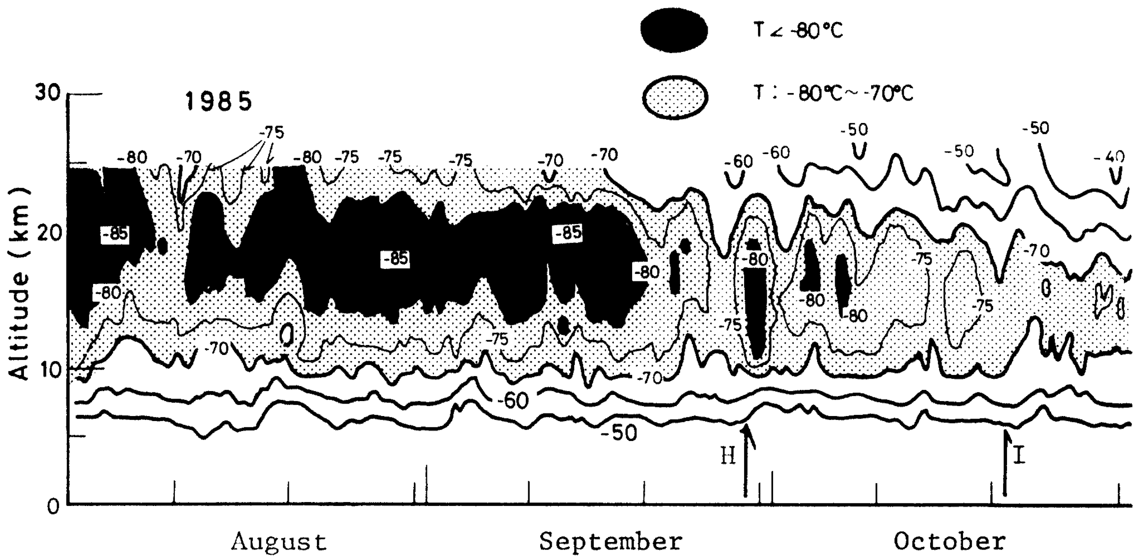

Fig. 2. Temperature distribution at Syowa Station (69°00′S, 39°35′E) in August, September, and October 1985.

3.4. Sudden increase due to short-lived cold air in spring

The aerosol content peaks of A, D and H are possibly due to an appearance of short-lived cold air (see example "H"). The mechanism controlling the pulsive increase is the same as the process which cause the winter enhancement.

4. Discussion

The winter enhancement is possibly caused by water vapor deposition-growth of ice particles and by a formation of new particle under very cold stratospheric conditions (IWASAKA, 1986b). Such a winter enhancement was observed not only in 1983 but also in 1985 (no measurement in the winter of 1984). Present observations confirmed that the winter enhancement occurred in every winter at the region with latitude =70 degrees.

The grade of the enhancement in 1985 is smaller than that in 1983. Comparing the values of particulate matter in the fully enhanced periods of both years, the load in winter of 1983 is about five times larger than that in winter of 1985. A winter enhancement strongly depends on stratospheric temperature. However we could not find any significant difference between the winter stratospheric temperatures of 1983 and those of 1985.

A possible explanation for the difference of the aerosol increase between the both winters is a volcanic effect of El Chichón (spring 1982, Mexico) on the Antarctic stratosphere. Concerning the duration of winter enhancement, the enhancement of 1985 lasted longer than that of 1983. The most effective factor causing this difference may be that the stratospheric temperature in September and October of 1985 was lower than that in 1983. The growth rate of ice particles with a decrease in atmospheric temperature, since the difference between saturation temperature and atmospheric temperature increases with decreasing temperature.

A number of investigators suggested that the volcanic eruption of El Chichón disturbed the Antarctic stratosphere (IWASAKA *et al.*, 1985c; HOFMANN and ROSEN, 1985).

Characteristic decay time has been used to discuss the after-effect of the volcanic eruption (IWASAKA, 1981; HAYASHIDA and IWASAKA, 1985). Because of the superimpose of the winter enhancement on the whole decay trend, it is not easy in our present case to discriminate the contribution from volcanic disturbance. Polar vortex in winter prevents airmass from transport from lower latitudes to higher latitudes. Therefore it may be useful to compare the winter result with the observed tendencies in spring, summer and fall, in order to discuss the diffusion of volcanic materials into the Antarctic stratosphere. Here we calculated the decay time from the data in the spring of 1984 and 1985, and we obtained a time constant of about 9 months. This value seems to be a little smaller in comparison with those from other investigations. As described by IWASAKA (1981) and HAYASHIDA and IWASAKA (1985), process controlling the decay of enhanced aerosol by a volcanic eruption is not only a diffusion but many other processes can be speculated. To clarify the problem it is necessary to know the temporal changes in aerosol size, concentration, and chemical composition at a number of locations over the world.

5. Conclusion

Lidar measurements from 1983 to 1985 at Syowa Station showed an enhancement of stratospheric aerosol layer in winter. However a pronounced difference was noticed in aerosol content between winter of 1983 and 1985. A long-term decrease in the content was found to take place in every springs. These seem to be a volcanic effect of El Chichón on the Antarctic stratosphere. It is necessary to obtain information about large scale air motion for a comprehensive understanding about diffusion of volcanic materials into the Antarctic stratosphere.

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